Chapter 1 — Basic Concepts

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Electric Circuit Analysis I (ESE 233) — Lecture no. 1

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Overview

Reference:

[1] Alexander Sadiku, Fundamentals of Electric Circuits, 4th ed. McGraw-Hill, 2009.

SI System of Units

An electric circuit is an interconnection of electrical elements.

TABLE 1.1 The six basic SI units.

Quantity	Basic unit	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd

The SI Prefixes

One great advantage of the SI unit is that it uses prefixes based on the power of 10 to relate larger and smaller units to the basic unit.

TABLE 1.2 The SI prefixes.

Multiplier	Prefix	Symbol
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

Electric Charge

Definition: *charge is an electrical property of the atomic particles of which matter consists, measured in coulombs (C)*

The following points should be noted about electric charge:

1. The coulomb is a large unit for charges. In 1 C of charge, there are $1/1.602 \times 10^{-19} = 6.24 \times 10^{18}$ electrons. Thus realistic or laboratory values of charges are on the order of pC, nC, μC.
2. According to experimental observations, the only charges that occur in nature are integral multiples of the electronic charge $e = 1.602 \times 10^{-19}$C.
3. The law of *conservation of charge* states that charge can neither be created nor destroyed, only transferred. Thus the algebraic sum of the electric charges in a system does not change.

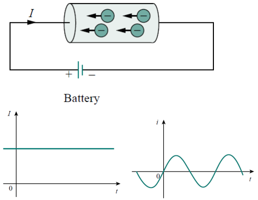
Electric Current

Definition: *Electric current is the time rate of change of charge, measured in amperes (A)*

$$i = \frac{dq}{dt} \longrightarrow q = \int_{t_0}^{t} i \; dt \qquad 1\text{ampere} = 1\text{coulomb/second}$$

Electric current can be classified into:

1. Direct current, I. A direct current (dc) is a current that remains constant with time.
2. Time-varying current, i. A common example is the sinusoidal current or alternating current (ac) which is the current that varies sinusoidally with time.



Examples

1. How much charge is represented by 4,600 electrons?
   Solution: Each electron has -1.602×10^{-19} C. Hence 4,600 electrons will have -1.602×10^{-19} C/electron $\times$ 4,600 electrons $= -7.369 \times 10^{-16}$ C
2. The total charge entering a terminal is given by $q = 5t \sin 4\pi t$ mC. Calculate the current at $t = 0.5$ s.
   Solution: $i = \frac{dq}{dt} = \frac{d}{dt}(5t \sin 4\pi t)$ mC/s
   $= (5 \sin 4\pi t + 20\pi t \cos 4\pi t)$ mA. At $t = 0.5$,
   $i = 5 \sin 2\pi + 10\pi \cos 2\pi = 0 + 10\pi = 31.42$mA

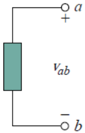
Voltage (Potential Difference)

Definition: *The voltage vab between two points a and b in an electric circuit is the energy (or work) needed to move a unit charge from a to b; mathematically,*

$$v_{ab} = \frac{dw}{dq},$$

$$1 volt = 1 joule/coulomb = 1 newton.meter/coulomb$$

where w is energy in joules (J) and q is charge in coulombs (C). Note that, $v_{ab} = -v_{ba}$



Current and voltage are the two basic variables in electric circuits.
The common term *signal* is used for an electric quantity such as a current or a voltage (or even electromagnetic wave) when it is used for conveying information.

Power and Energy

- Although current and voltage are the two basic variables in an electric circuit, they are not sufficient by themselves.
- For practical purposes, we need to know how much power an electric device can handle.

Definition: *Power is the time rate of expending or absorbing energy, measured in watts (W).*

$$p = \frac{dw}{dt} = \frac{dw}{dq} \cdot \frac{dq}{dt} = vi,$$

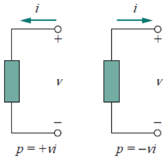
where p is power in watts (W), w is energy in joules (J), and t is time in seconds (s).

Power and Energy (cont'd)

- Current direction and voltage polarity play a major role in determining the sign of power.
- It is therefore important that we pay attention to the relationship between current i and voltage v

Passive sign convention is satisfied when the current enters through the positive terminal of an element and $p = +vi$. If the current enters through the negative terminal, $p = -vi$.

In this case, $p = +vi$ implies that the element is absorbing power. However, if $p = -vi$, the element is releasing or supplying power.



Power and Energy (cont'd)

Law of energy conservation: "In any electric circuit, the algebraic sum of power in a circuit, at any instant of time, must be zero"

$$\sum p = 0$$

This again confirms the fact that the total power supplied to the circuit must balance the total power absorbed.

Energy is the capacity to do work, measured in joules (J).

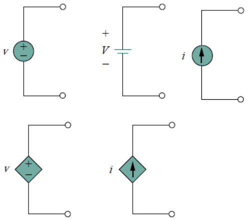
$$w = \int_{t_0}^{t} p dt = \int_{t_0}^{t} vi dt$$

The electric power utility companies measure energy in watt-hours (Wh), where 1 Wh = 3,600 J

Circuit Elements

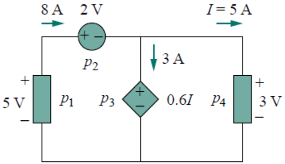
Ideal independent source: An ideal independent source is an active element that provides a specified voltage or current that is completely independent of other circuit variables.

Ideal dependent source: An ideal dependent (or controlled) source is an active element in which the source quantity is controlled by another voltage or current.



Example: Compute the power absorbed or supplied by each component of the circuit shown.

Answer: p1 $= -40$ W, p2 $= 16$ W, p3 $= 9$ W, p4 $= 15$ W.



Conclusion

Concluding remarks

- Introduction to electric circuits is introduced.
- Basic electric quantities are defined with examples.
- Fundamental circuit elements (sources) are addressed.
- Some illustrative examples are discussed.